DEPARTMENT OF AGRICULTURE, INSURANCE, STATISTICS, AND HISTORY.

GEOLOGICAL SURVEY OF TEXAS.

E. T. DUMBLE, State Geologist.

BULLETIN No. 2.

A PRELIMINARY REPORT

ON THE

SOILS AND WATERS

OF THE

UPPER RIO GRANDE AND PECOS VALLEYS

IN

TEXAS.

By H. H. HARRINGTON,

Professor of Chemistry and Mineralogy, Agricultural and Mechanical College of Texas.

AUSTIN:
STATE PRINTING OFFICE.
1890.

LETTER OF TRANSMITTAL.

Hon. L. L. Foster, Commissioner of Agriculture, Insurance, Statistics, and History:

DEAR SIR — I transmit for publication "A Preliminary Report on the Soils and Waters of the Upper Rio Grande and Pecos valleys," by Prof. H. H. Harrington. The work of collecting and the study of these soils and waters was carried on by Prof. Harrington without any personal remuneration whatever, the Survey paying only his actual expenses while in the field, and it is therefore eminently proper that the thanks of the Survey be thus publicly expressed for his kind assistance in the preparation of this Bulletin.

Yours, very truly,

E. T. DUMBLE,
State Geologist.

AUSTIN, TEXAS, February 15, 1890.

INTRODUCTION.

The question of irrigation along the upper Rio Grande being one of great importance to the citizens of El Paso County and to the State generally, it was decided that an examination of the soil and water of that section should be made in order that there might be proper data from which to discuss the feasibility of irrigation should a suitable dam be built above El Paso. Prof. H. H. Harrington, of the Agricultural and Mechanical College, was selected to make the investigation, and in the report herewith submitted he gives the results of his work.

To this is added a like discussion of the soils of the Pecos Valley and water of the Pecos River. These specimens were collected under the instructions of this department by Mr. B. K. Brant, and represent the characteristic soils of that region.

The results show clearly the absolute necessity for just such investigations as are here recorded. The examination of the soils of the Rio Grande and Pecos valleys proves that they are equally fertile and that both need only the requisite supply of suitable water to render them highly productive.

Irrigation has been carried on for years on the Rio Grande, and the results obtained in practice fully corroborate those brought out by the chemical analyses of the water of that river as regards its entire suitability for irrigation, if it can be obtained in proper quantity.

Preparations are now being made to use the water of the Pecos River for irrigating the lands lying in the valley. The analysis of this water shows that it contains so large a quantity of salt as to make it advisable to proceed with the utmost caution in this work. It is true that salt, being readily soluble in water at all temperatures, would be carried off to a greater or less extent by the rains falling upon the soil during the year, but it would seem rather a dangerous experiment to put the amount of salt as shown upon soils already amply supplied with alkaline material, even with all the possibilities of its being leached out again by later rains. The danger is more fully shown if we take into consideration the existence of such spots as are described under soil specimen No. 4, which offer strong proof that the rainfall is entirely insufficient to accomplish a work of this kind.

The results of the analyses of the Pecos water are fully verified by the report of Mr. C. C. McCulloch, Jr., of this Survey, who made a personal examination of the river and new canal. He says: "The banks of the river are lined with incrustations of salt left by the evaporation of the river water, and present a very white appearance to the eye. The sides of the canal are similarly incrusted, and the salt appears in places in spots on the ground. I did not observe any salt spots in the freshly irrigated fields. The water does not taste salty and is used for drinking purposes." (It requires over 150 grains of salt per gallon to give any salty taste at all.)

The difference in the character of the water of the two rivers is readily explainable, being due entirely to the difference in composition of the geologic formations through which they pass. The Rio Grande flows down through the harder materials of the Rocky Mountains, and carries little besides red clay in suspension, while the Pecos cuts through the softer strata of the Permo-Jura-Trias, containing beds of salt and gypsum. It must be fully understood, however, that the conclusions reached concerning the use of Pecos River water apply only to that stream and not to the various other sources of water supply in the Pecos country.

One very valuable fact brought out by this investigation is the relation existing between the amount of lime contained in certain soils in Western Texas and the difference of vegetal growth thereon—those low in lime bearing only cacti and those containing a higher percentage carrying a fine growth of mesquite. The importance of this determination is immediately apparent to any one who has ever seen the treeless expanses of Western Texas.

The results shown and conclusions reached by Prof. Harrington are presented with the hope that they will prove of especial value to those in any way interested in Western Texas, and as showing most plainly the intimate relations which exist between chemical geology and many questions of practical agriculture.

E. T. DUMBLE.

SOILS AND WATERS

OF THE

UPPER RIO GRANDE VALLEY IN TEXAS.

BY

H. H. HARRINGTON.

Professor of Chemistry and Mineralogy, Agricultural and Mechanical College of Texas.

Mr. E. T. Dumble, State Geologist:

SIR—Having been detailed by your Survey for special work upon the soils of the upper Rio Grande valley in this State, and for an inquiry into the economic aspects of that country as related to agriculture and its allied arts, I have the honor to present herewith my report on the work done.

The analytical part of the work was executed by Mr. P. S. Tilson, chemist of the Geological Survey, at the laboratory of the Agricultural and Mechanical College.

I beg to acknowledge the many kindnesses shown me in camp by Mr. W. H. Streeruwitz, geologist for Western Texas, special favors by Messrs. Rubenstein and Buchanan of Ysleta, Mr. S. J. Etheridge of San Elizario, and the courtesies of the railroad employes at Sierra Blanca.

Yours, very truly,

H. H. HARRINGTON, Chemist.

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS,

December 1st, 1889.

SOILS AND WATERS

OF THE

UPPER RIO GRANDE VALLEY IN TEXAS.

The investigation into the character of the soils of the upper Rio Grande Valley as planned, consisted of a personal examination of that part of El Paso County adjacent to the Rio Grande from El Paso to a line below the site of Fort Quitman, for the purpose of ascertaining the character of soils and of the water supply, with especial regard to their capacity and suitability for irrigation.

The scope of country investigated is some eighty miles in length and from two to six miles in width, varying with the breadth of the valley, upon the Texas side of the Rio Grande, and having an average width of about three miles. For this entire length the valley is either traversed or skirted by the G. H. & S. A. R. R. and the T. & P. R. R., these railways using the same track from El Paso to Sierra Blanca, ninety miles southeast. For about thirty miles below El Paso the greater part of the valley is now under cultivation In many instances the orchards and vineyards are brought up to the highest state of perfection, rivaling in beauty and value those of the Pacific Slope. Many varieties of grapes are grown in the most satisfactory manner. Pears, peaches, apples, and plums are also found in many different orchards. Vegetables of almost every variety and melons of different kinds give the most satisfactory returns to the market gardener. Of the farm crops proper, corn, oats, wheat, rye, and alfalfa seem to be the most important. Alfalfa is grown in great quantity and, as represented by responsible and prominent farmers in the valley, very profitably; from two to four cuttings are made during each season, and from two to three tons to the acre are produced at each cutting, the value of which is from ten to fifteen dollars per ton. These variations in the quantity raised are dependent almost entirely on the supply of water for irrigation. The supply of irrigating water as managed at present is entirely inadequate to meet the demands of the valley, or even to properly supply that portion of it now under cultivation. In many instances a crop is entirely lost from a want of a supply of water at the proper time, and often water is obtained too late to give anything like satisfactory results. In consequence of this and of the class of farm laborers employed, farming proper is very improperly managed and conducted. Most of the Americans living in the valley give their attention to viticulture, orchards, or market gardening. The farms are generally rented by Mexicans, whose system of agriculture is very crude. They use no improved implements and do their cultivating entirely by hand, which of course operates very much against the rapid development of the country in this direction. As a proof of this statement, and of the scarcity of the supply of water at present, I need only say that land valued at from twenty to forty dollars an acre can be rented at from twenty-five cents to one dollar an acre. It is true that this is in part explained by the land being held at speculative prices; but the same conditions must prevail to a large extent until the system of labor is changed and agriculture be conducted more in accordance with the recognized principles of that industry.

SOILS.

The soils of the valley may in a general way be divided into three classes:

First—The heavy "adobe" soil of the river deposit.

Second—The sandy loam, being an intimate mixture of the adobe soil with the sand of the foothills adjacent to the valley.

Third—The sandy soil, containing an excess of the sand from the foothills.

The adobe soil is the most difficult to cultivate, is plastic, and is generally supposed to contain a larger amount of alkalies than either of the other soils. The sandy soil is regarded as the best adapted for vegetables and alfalfa, while the sandy loam, which is the predominating soil, is used for various crops.

Adobe Soil.—This soil was taken from the valley between El Paso and Juarez (Paso del Norte), Mexico. So far as could be judged it was selected as a typical "adobe" soil.

CHEMICAL ANALYSIS.

	Per Cent.
Volatile and organic matter	9.17
Soluble silica	0.21
Insoluble silica	76.01
Ferric oxide	3.20
Alumina	4.04
Phosphoric acid (anhydrous)	0.12
Sulphuric acid (anhydrous)	0.31
Lime CaO	3.53
Carbonic acid gas	2.05
Alkalies as chlorides	3.24
	101.88

MECHANICAL ANALYSIS.

	Per Cent.
Siftings	15.39
Sand, .25 to .05 mm.	39.71
Silt, .05 to .01 mm.	4.97
Dust, .01 to 0 mm.	24.01
Clay (by difference)	4.79
Loss on ignition	11.13
	100.00

The soil gives a faint alkaline reaction in cold solution; distinctly alkaline on boiling. The chemical analysis makes a good showing for the soil. The "chlorides" consist principally of common salt. The quantities of organic matter, lime, iron, sulphuric and phosphoric acids, are such as are found only in productive soils.

SANDY LOAM.—The following is the analysis of two samples of the sandy loam soil from near San Elizario Station, about thirty miles below El Paso. There is little difference in the analyses of the two samples, and comparatively little between these and that of the "adobe" soil, except that the quantity of sand is considerably increased while the organic matter is very much less. There is, according to the popular opinion, a slight excess of alkalies in the "adobe" soil. From the examination made I think that this slight excess will prevail throughout the entire valley. The alkalies in these samples also consist principally of common salt. There appears to be little of the highly corrosive carbonate of soda in any of these soils which is so prevalent in the waters and soils of California and States and Territories of the Northwest.

CHEMICAL ANALYSES.

	1	2
Organic and volatile matter	4.48	4.45
Soluble silica	0.12	0.13
Insoluble silica	82.43	82.37
Ferric oxide	3.04	2.24
Alumina	1.67	1.95
Phosphoric acid (anhydrous)	0.29	0.36
Lime	3.68	3.79
Magnesia	0.15	Trace
Sulphuric acid (anhydrous)	0.94	0.28
Carbonic acid gas	2.06	2.46
Alkalies as chlorides	2.54	3.03
	101.40	101.06

MECHANICAL ANALYSIS.

	Per Cent.
Siftings	1.91
Sand, .25 to .05 mm	78.02
Silt, .05 to .01 mm	7.48
Dust and clay, (.01 to 0 mm. by difference)	5.82
Loss on ignition	6.77
	100.00

The analyses of these two examples of this soil fully explain and sustain the great fertility shown in the practical cultivation of the crops. The small percentage of sulphuric acid and the comparatively large amount of carbonic acid shows that the lime is present as limestone or carbonate, and not as gypsum or sulphate.

The quantity of alkalies, soda and potash, as reported in all these soils, is much larger than is generally found in soils. It is a well known fact that an excess of common salt is injurious to plant growth. But exactly what constitutes this excees has not, so far as I know, been determined; but it is certain that the maximum limit has not been reached in the case of these soils, as is evidenced by their exceeding fertility. In certain cases small quantities of salt are beneficial to land, and it frequently gives good results when applied as a fertilizer; but the quantity in which it is applied is never sufficient to constitute anything but a small fraction of one per cent of the soil. In these cases its office seems to be not to act as plant food itself, but to decompose the double silicates of lime and potash and set them free and render them available as plant food. When there is a slight excess of salt it checks the rank growth of plants, and if the excess is considerable the plants will be destroyed entirely, particularly if the salt comes in contact with the roots of young plants. It has also been determined in case of certain alkali soils that were entirely barren that by decreasing the quantity of alkali the soil was restored to fertility: but so far as I can ascertain the maximum quantity of alkali that any one crop would tolerate and still thrive and do well has not been determined. The character of the soil would undoubtedly have great influence in this matter. The consideration of this question is of great importance in certain districts where the soil already contains considerable quantities of alkali and is to be irrigated with a water also carrying alkali in solution, which amount is to be added year by year to the amount already accumulated in the soil.

CHEMICAL ANALYSES OF SOILS FROM FOOTHILLS AROUND SIERRA BLANCA AND BORDERING THE RIO GRANDE VALLEY.

	No 1.	No. 2.	No. 3.	No. 4.	No. 5.
Organic and volatile matter	8.33	4.19	7.65	3.10	4.26
Soluble silica	0.44	0.73	0.29	0.17	0.13
Insoluble silica	78.63	88.26	74 85	66.55	81.88
Ferric oxide	7.44	1.44	4.08	2.88	3.36
Alumina	2.22	1.12	3.84	1.45	2.70
Phosphoric acid (anhydrous)	0.34	0.25	0.60	0.21	0.19
Lime, CaO	0.57	1.28	3.83	13.65	3 84
Magnesia, MgO	...	Trace	Trace	0 96	0.81
Sulphuric acid (anhydrous)	0.38	0.58	0 73	Trace	0.78
Carbon dioxide	Trace	0.60	2.13	9.52	2.10
Potash, K_2O	0.52	0 33	0.43	0.47	0.26
Soda, Na_2O	0.46	0.78	0.85	0.29	0.67
	99.33	99.57	99.28	99.25	101.26

No. 1 comes from ten miles north of Sierra Blanca, and is a red sandy soil.

No. 2 is from the valley three miles northeast of Sierra Blanca.

No. 3 is from ten miles west of north of Sierra Blanca, the grass being excellent.

No. 4 is from eight miles south of Sierra Blanca. The grass is good, and an excellent growth of mesquite brush.

No. 5 is from Sierra Blanca.

The noticeable features of these soils are the large quantity of iron they contain, and the comparatively large amounts of potash and phosphoric acid, excepting nitrogen, the two most valuable ingredients a soil could contain. The percentages of lime, carbonic and sulphuric acids are rather small for Texas soils, but still sufficiently large for agricultural needs. One important fact, however, should not go unnoticed. In No. 4 the quantities of lime and carbonic acid are both large, showing that the lime is present as the carbonate; and on this soil there is not only a good growth of grass, but the mesquite underbrush is thick and weighted with fruit. This is an exception to the general growth of the foothills. Usually there is plenty of nutritious grass, but little else except cacti. In the spot where No. 4 was collected the cactus is entirely replaced by the mesquite. In a general way, we may say there is little doubt but that lime applied to these soils, either as the sulphate, gypsum, or as the carbonate, would be beneficial. The absence of "alkalies" is a very fortunate characteristic of the soils.

ALKALI SPOTS.

The Rio Grande valley, as I observed it, is dotted with spots of alkali. They seem to occur irregularly, anywhere in the valley. Sometimes they have been brought into cultivation, but more frequently they are left alone as not being worth the trouble and expense of reclaiming. They vary in area from one-fourth of an acre to eight or ten acres. I have submitted the incrustation of some of the uncultivated spots to a partial analysis:

SOIL INCRUSTATION.

BLACK ALKALI.—From Ysleta, Texas—

	Per Cent.
Lime	4.48
Sulphuric acid (anhydrous)	6.39
Carbonic acid gas	2.23
Soda (oxide of sodium)	11.23
Potash (oxide of potash)	.09
Chlorine	6.53

The soda is present as chloride, sulphate, and carbonate; the lime as silicate and carbonate. This analysis represents a sample of what is known as "black alkali," to distinguish it from a white incrustation, which is known as "white alkali." As far as observed by me the chief difference between the two is the more complete sep^ration of sodium chloride in the "white alkali." Another specimen from the valley ten miles below Fort Hancock gave on partial analysis:

	Per Cent.
Lime	7.73
Sulphuric acid (anhydrous)	.51
Carbonic acid gas	2.80
Soda (oxide of sodium)	1.16
Potash (oxide of potassium)	0.41
Chlorine	1.16

A remarkable feature in this incrustation is the presence of chloride of lime. Sodium carbonate is also present. The two together make an exceedingly viscous combination. The sample of incrustation is very hygroscopic When taken it was moist, although taken from a climate that is so dry as to partially dehydrate citric acid. It would be classified as black alkali, and comes from an adobe soil.

WHITE ALKALI.—An incrustation from the Rio Grande valley above El Paso, in New Mexico, showed in 100 parts of the material, which were soluble in water and which amounted to forty per cent of the entire mass:

50.99 parts alkalies as chlorides.

3.87 parts of lime.

19.77 parts of sulphuric acid.

Phosphoric acid and magnesia absent.

This is a sample of white alkali.

RECLAIMING ALKALI SPOTS.

To accomplish this result various methods are resorted to. Beets grown upon the soil seem to dissipate the alkali. Barnyard manure, when it can be obtained, improves the condition very much. Sometimes simple cultivation without an attempt to grow any crop is practiced with very favorable results. If irrigation can be applied the chlorides are soon carried away, or below the surface, and where only chlorides are present the spot is rapidly brought to a state of cultivation. Unfortunately this cannot be generally done since the supply of water is not even sufficient for the crops. Frequently sorghum is grown, which is a profitable money crop, and valuable for reclaiming the soil. Gypsum has not, so far as I could learn, been used. But in many instances its use would probably be attended with the most satisfactory results, while in other cases it would probably be of little benefit.* In all cases the alkali should be subjected to chemical analysis, and then intelligent methods could be directed for reclaiming the soil.

SEDIMENTS.

In the ditches used for irrigating there accumulate considerable quantities of mud and other matter, which is carried by the river water in suspension and in solution. This deposit, when it becomes dry in the bottom of the ditches, cracks, curls and breaks into pieces of various sizes. From time to time it is removed and thrown upon either side of the ditch, the banks of which are gradually built up. Below are given the analyses of two samples of this deposit. There is considerable difference in the composition of these sediments, owing to the difficulty of collecting the deposits in a state of purity, and even more due to the nature of the soil underlying the ditch. The frequent alternations of flooding and evaporation of water from the bottom of the ditch will ultimately accumulate at the surface all the alkali which exists in the soil to a considerable depth. Hence in collecting a sample of the sediment, should it happen to be from a place where the ditch passes over an alkali spot, the quantity of alkali shown by analysis is likely to be much greater than would appear in the analysis of a sediment gathered from any other place.

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*Large quantities of gypsum have just been found west of the Quitman Mountains, which is directly in the line of the railroad, and within a few miles of this valley, being, in fact, in the line of hills which forms its southern boundary. E. T. D.

RIVER SEDIMENTS.

From San Elizario Station. Partial analysis.

	1	2
Organic matter	2.77	0.00
Lime	5.60	3.78
Sulphuric acid (anhydrous)	0.59	2.94
Soda (oxide of sodium)	11.23	16.56
Potash (oxide of potassium)	.09	1.65
Carbonic acid gas	3.44	1.65

We have only to look at the percentage quantities of soda in these to be convinced as to the accumulation of alkali; but they come from old ditches where accumulation has been going on for some time, and do not fairly represent a river deposit. This could be obtained with accuracy only by allowing the water to settle in a clean vessel, and collecting the sediment from that.

WATER SUPPLY.

This is the one question upon which the development of the valley depends. Without water of the proper kind in the valley, and in sufficient quantity for irrigation, very little progress can be made. With a proper water supply the capabilities of the valley can hardly be overestimated. In various places water can be found within eight feet of the surface—in a bed of quicksand—it is said; but the quantity is sufficient only for family purposes, and in many cases is not well adapted even for this use. The quantity of alkali is excessive, often so much as to kill young plants where used for irrigation. It is generally understood that the best water obtained at or about this depth is from the old river bed, which traverses almost every part of the valley, in which the water is better, because the alkali is less. It is supposed that in the old river the water dissolved and carried away the alkali from the soil adjacent to its bed. So far as I could ascertain no decided effort has been made to obtain artesian water in the valley. At Fort Hancock, fifty miles below El Paso, the post bored 225 feet, but obtained no water. I think that this is the greatest depth that has been reached in the valley, and it is not sufficient to make a satisfactory test of the matter. However, some geologists have expressed the opinion that flowing water can not be obtained here.

On the foothills, at various points along the Galveston, Harrisburg & San Antonio Railroad, more or less removed from the valley, water has been obtained at depths varying from 700 to 2000 feet. Not flowing water, but within easy pumping distance. At Fabens, 35 miles from El Paso, water was obtained at a depth of 27 feet. The well furnishes, by pumping, all the water necessary for the railroad storage tanks located at this place. I have no analysis of this water, but think it is comparatively free from alkali. If so, and other wells could be obtained like it, it would perhaps be the simplest solution of the irrigation problem. On the mesa, eight miles northeast of El Paso, the Lanoria Mesa Company are sinking a system of wells, with the object of irrigating and improving the mesa. The mesa is a level plain having an elevation of one hundred and eighty feet above the level of the valley at El Paso. On the west it abuts against the precipitous cliffs of granite, limestone, and porphyry, which are much tilted. Some miles to the east the plain breaks into hills; small, but steep cliffs, and shallow, but sometimes precipitous canyons. It is the same general contour of country found bordering the east side of the valley for two hundred miles or more.

The following are the strata as described by the engineer who bored one of the wells on the mesa.

Surface clay	18 feet
Sand and gravel	45 "
Clay	10 "

Sand and clay alternate from this until a depth of 230 feet is reached, where there occurs a bed of sand and gravel mixed, which is seventy-four feet in thickness. This is the depth at which water is first obtained. After passing through the bed of sand and gravel, and through a bed of clay ten feet thick, a large quantity of water is obtained in a bed of sand twenty-four feet thick, resting presumably upon a bed of clay. The well is 340 feet deep, the depth of water being 120 feet.

The water is pumped by windmills. While the capacity of the well is not known, it has furnished, so the company informed me, 16,000 gallons in twenty-four hours without lowering the column of water in the well.

ANALYSIS OF MESA WELL WATER.

	Gr. to Gal.
Suspended matter (inorganic)	2.80
Total solid residue in clear solution	36.65
Organic and volatile matter	6.15
Total mineral matter	30.20
Again soluble	29.80
Lime	3.63
Alkaline chlorides	3.19
Sulphuric acid (anhydrous)	5.52

The water has an alkaline reaction in the cold, which is increased by boiling; is clear and colorless, and the suspended matter settles easily. The sample was sent in a sealed demijohn, and when opened emitted considerable odor of sulphuretted hydrogen, but the quantity was not sufficient to estimate. While the total amounts of soluble mineral matter and alkaline chlorides are somewhat large, they are not sufficient to interfere with the use of the water for irrigating purposes. The water may be said to be free from any alkaline taste, and is an excellent drinking water.

ANALYSIS OF RIO GRANDE WATER.

	Gr. per Gal.
Suspended matter (inorganic)	98.65
Total residue in clear water	40.65
Organic and volatile matter	5.05
Total soluble matter	29.15
Lime	4.65
Sulphuric acid (anhydrous)	3.23
Alkaline chlorides	1.77

Silica, iron, and alumina not determined.

The water when collected was very muddy, hence the large amount of suspended inorganic matter, which is more than twice the quantity of matter held in solution. It has a slight alkaline reaction. The river water has for a long time been used for irrigating; indeed, it is the one source of supply for that purpose at present. The fact that it will rapidly remove alkali from alkali spots in the valley is most conclusive evidence of its value for irrigating purposes. The water contains a comparatively large quantity of gypsum and of potash, two substances that add greatly to the fertility of most soils. The quantity of mineral matter, as carried by the river water and in a finely divided state deposited from time to time over the surface of the soil, tends to improve its mechanical condition and to add to its fertility.

Quantity of River Water.—The great obstacle in the way of irrigation in the valley at present is the insufficient quantity of river water, which is not sufficient to supply even the present demands made upon it, much less to permit any increase in the acreage of cultivation, as there is a constantly growing desire to do. During the early part of the year the river usually furnishes all the water now needed, but as the season advances the supply grows less, and many crops that come up and start well to growing are entirely lost from insufficient water supply. At some time in the early summer, when the ice melts on the upper tributaries of the river, there is a rise for a short time, not being of sufficient duration, however, to be of much value for irrigating.

Until good water is supplied in sufficient quantity there can be no increasing and permanent prosperity in this valley. There is one way to increase the water supply from this source, and this is by the construction of storage tanks, and by holding back the high water of the river for distribution to the growing crops later in the season. If this is done in a systematic and scientific way, it will make the upper portion of the Rio Grande Valley one of the most desirable districts in the State.

Water Reservoirs or Storage Tanks.—In many places along the foothills, contiguous to the valley, water reservoirs could be easily and economically constructed at the mouth of gorges and across channels of mountain streams. The water so obtained might not generally be sufficient for irrigating on an extensive plan, because the rainfall is hardly sufficient for the accumulation of such large bodies of water, in addition to which the exceedingly dry climate, with a constant wind, that might be often called a gale, would rapidly evaporate water from such accumulations. The fact is frequently advanced as an argument against the expediency of building water reservoirs in this climate; but I believe such tanks could be constructed with profit, where the aim is to combine cattle raising with farming. There is at present in El Paso county a tank formed by the old bed of the Texas & Pacific Railroad crossing the channel of a mountain valley; here, some 1500 head of cattle are supplied with water for many months. The foothills are covered with a good supply of gamma grass, which is very nutritious, and of which stock are very fond. It serves alike for summer and winter pasturage. In the valley there is comparatively no grass; although there are some 6000 head of cattle in the valley from El Paso down to Fort Quitman. Many of these cattle range on the foothills, and travel eight or ten miles daily to the river for water. During the winter they do not go nearly so frequently, as the Prickly Pear cactus furnishes them nearly all the water they require. If water could be supplied in the foot hills many cattle could be pastured there, while small plots of ground could be irrigated, furnishing an orchard, garden, lawn, etc. As the number of tanks increased, the humidity of the atmosphere would increase, lessening evaporation, and if not increasing the rain fall, would at least make possible the accumulation and retention of large bodies of water. Again, I believe water within very easy pumping distance might be obtained at many places among the foothills.

Nature of Alkali in the Valley.—So far as I have investigated this subject, I have found that common salt is the chief disturbing substance, though in one case chloride of calcium was found; and in other cases very small quantities of the alkaline carbonates may be present. As a rule, these are absent, except in mere traces. Still small amounts of gypsum should be used to neutralize whatever carbonate may be present. The sodium carbonate is exceedingly pernicious to the development of young plants. The chlorides can be removed, as mentioned above, by irrigation, blank cultivation, and application of barnyard manure. I believe that the value of the latter as a fertilizer is itself increased by the presence of common salt, if the quantity is small. Then such crops as beets, sorghum, alfalfa, should be grown until the land is brought into good tilth.

CONCLUSIONS.

1. The soil of the valley is exceedingly fertile, not heavily charged with alkali except in spots, and these can be reclaimed without great difficulty.

2. The water obtained eight feet below the surface in a bed of quicksand is too strongly alkaline for irrigation purposes, and is not even a good drinking water, although it is now so used.

3. The river water is well suited for irrigation; the quantity of mineral matter is large, as is that of the alkali chlorides compared to quantities in other river waters. The matter in suspension probably adds to the fertility of the soil.

4. The quantity of river water, under present conditions, is not sufficient to meet present demands. It should be collected in storage reservoirs during high water, and held for growing crops later in the season.

5. The present system of irrigation is unsatisfactory, inefficiently constructed, and badly managed. Farmers in the valley would gladly pay higher rates for more water and a better distribution of it.

6. The artesian water from the mesa hills is not so adaptable for irrigating purposes as is the river water; but it is sufficiently pure for use.

7. In many instances water could be collected in the foot hills by reservoirs, and cattle raising and farming combined with profit.

8. The system of labor in the valley is exceedingly defective and unsatisfactory; but this is a matter that will regulate itself with the improved conditions of the water supply.

9. The alkali can be removed by irrigation, deep and thorough cultivation, application of gypsum, manuring with barnyard manure, or by growing special crops that are conducive to the removal of saline matter. In all cases the work should be preceded by a chemical analysis of the soil.

SOILS AND WATERS OF THE PECOS VALLEY.

PECOS VALLEY SOILS.

I present, in addition to the above report, analytical work done by Mr. P. S. Tilson upon the Pecos Valley soils, and analyses of Pecos River water. The soils and water were collected under your direction and sent by you to this laboratory for examination. The following explanation and description was received with the samples:

No. 1. Upland loam, west side of Pecos River; very deep without apparent change.

No. 2. From the surface soil of Pecos City, one inch to two feet in depth; rests on No. 3.

No. 3. From twelve to fifteen feet deep.

No. 4. Exists in patches from ten feet in diameter to ten acres or more. Alkali soil.

No. 5. From river bank, west side, three hundred feet back from river, very deep.

No. 6. Upland soil from east side of river; averages eight inches in thickness; rests on No. 7.

No. 7. Eight inches thick; rests on No. 8.

No. 8. Dug about twenty inches into this; saw no change in the character.

No. 9. From east valley four hundred feet back from river; about ten inches in thickness; rests on No. 10.

No. 10. About six inches in thickness; rests on No. 11.

No. 11. Depth unknown.

ANALYSES OF PECOS VALLEY SOILS.

	Organic and Volatile Matter.	Soluble Silica.	Insoluble Silica.	Ferric Oxide.	Alumina.	Phosphoric Acid.	Lime.	Magnesia.	Sulphuric Acid.	Carbonic Acid.	Alkalies as Chlorides.
No. 1	11.97	0.26	58.7	3.20	7.78	0.13	5.6	0.30	4.1	5.1	2.3
No. 2	5.25	1.10	72.3	2.16	2.50	.08	5.6	3.2	2.0	3.5	2.6
No. 3	15.5	34.8	19.0	0.86	1.60	.09	12.6	0.6	11.4	2.3	2.0
No. 4	13.	.07	49.	2.97	4.12	Trace	12.6	2.2	2.5	7.3	6.1
No. 5	9.12	0.17	68.6	5.65	1.42	0.12	7.0	0.8	1.0	5.5	1.5
No. 6	6.7	0.14	77.0	4.47	0.73	0.21	5.2	Trace	0.9	3 2	2.3
No. 7	2.8	.03	85.5	2.42	1.89	0.14	3.3	0.62	1.1	1.4	2.7
No. 8	2 5	.04	87.7	1.27	0.44	0.09	2.1	0.2	1.26	3.1	1.5
No. 9	8.44	0.10	69.2	3.86	5.54	0.21	4 7	Trace	1.7	4.8	3.1
No. 10	8.02	4.2	60.1	3.14	5.11	0.2	8.5	Trace	5.0	5.6	1.2
No. 11	15.3	9.1	34.3	2.56	2.00	0.6	13.3	0.9	16.9	3.9	1.3

MECHANICAL ANALYSES OF PECOS VALLEY SOILS.

No. 1.

Upland loam, west side of Pecos River:

	Per Cent.
Siftings	0.69
0.25 to .01 mm	34.58
.05 to 0.1 mm	35.05
.01 to 0 mm	11.44
Clay (by difference)	2.02
Loss on ignition	16.22

No. 2.

From the surface soil of Pecos City:

Siftings	1.72
0.25 to 0.05 mm	76.18
.05 to .01 mm	7.62
.01 to 0 } by difference Clay }	4.31
Loss on ignition	10.17

9.69 per cent of sand was removed by the 0.1 mm seive. This was added to the 0.25–0.05 mm.

No. 3.

Siftings	1.06
0.25 to 0.05 mm	19.18
0.5 to 0.01 mm	5.22
.01 to 0 mm	54.04
Loss on ignition	20.50

No. 4.

Siftings	1.45
.25 to .05 mm	37.53
.05 to .01 mm } † .01 to 0 mm }	34.29
Clay (by difference)‡	3.65
Loss on ignition	23.08

†These two quantities seem to be about equally divided between .05–.01 mm. and .01–.0 mm.
‡Clay determined by 30 hours subsidence.

No. 5.

Siftings	0.39
.25 to .05 mm	50.29
.05 to .01 mm	19.56
.01 to .0 } by difference Clay }	7.67
Loss on ignition	13.09

No. 6.

Siftings	0.78
.25 to .05 mm—Sand*	75.43
.05 to .01 mm	11.12
.01 to .0 mm (by difference)	5.46
Loss on ignition	7.21

*13.96 per cent of sand was removed by the 0.1 mm sieve. This was added to the sand and the whole amount is included in above percentage.

No. 7.

Siftings	0.51
.25 to .05 mm—sand †	85.50
.05 to .01 mm	6.70
.01 to 0 mm (by difference)	2.34
Loss on ignition	4.95

†26.16 per cent of sand was removed by the 0.1 mm seive, which, added to the sand proper, gives the amount here quoted.

No. 8.

Siftings	0.41
.25 to .05 mm	92.73
.05 to .01 mm	2.82
.01 to 0 mm (by difference)	1.35
Loss on ignition	2.69

No. 9.

Siftings	1.76
.25 to .05 mm	34.91
.05 to .01 mm	19.12
.01 to 0 mm	11.64
Clay‡	19.33
Loss on ignition	13.13

	No. 10.	No. 11.
Siftings	10.4	2.93
.25 to .05 mm	61.71	29.59
.05 to .01 mm	8.71	17.39
.01 to 0 mm	7.33	10.10
Clay‡	5.67	19.70
Loss on ignition	15.54	20.28

‡ Clay was determined by difference, and contains that part of the grade having diameters from .01 to 0 mm, which remains suspended after 24 hours subsidence.

The mechanical analyses of the soils herein reported were made according to Dr. Osborne's method—that of Beaker Elutriation. Particles having diameters between .25 and .05 mm., are designated as *Sand;* those between .05 and .01 mm. as *Silt;* those below .01 mm. as *Dust*, or as Dust and Clay. There is no thoroughly reliable method of mechanical soil analysis. But this method and that of Hilgard's Churn Elutriator method give most satisfactory results, the work by either method approaching accuracy sufficiently to give a very correct idea as to the general mechanical condition of the soil. It will be noticed that these soils are mostly sandy; but in a few instances, the quantity of fine material is very great. In No. 3 the *Dust* is particularly large in quantity.

From the description No. 1, upland loam, seems to occupy considerable extent of country. Its analysis indicates an excellent soil. The subsoil is probably of the same general character as the top soil. No. 2 is a chocolate loam, having No. 3 as a calcareous subsoil. This lime is present as the carbonate and as the silicate. No. 4 is an alkaline loam, with a large quantity of organic matter present. The quantity of chlorides present is too large to permit its use. No. 5 is a red alluvial soil. Nos. 6, 7, and 8 are superimposed. The surface soil, No. 6, a black sandy soil; No. 7 has less organic matter and more sand; while No. 8 is almost pure sand. It is also noticeable that there is a gradual decrease of phosphoric acid and lime from the surface down. The quantity of alkalies in No. 8, sixteen inches below the surface, seems to have decreased very much. This is in keeping with the general tendency of alkalies to accumulate near the surface. Nos. 9, 10, and 11 are also superimposed. In this case there is an increase of organic matter from the surface down. The conditions are almost the reverse of Nos. 6, 7, and 8, though in 9, 10, and 11 none of them is so distinctly sandy. The deepest soil is in this case really the best soil. There is less sand, more organic matter, lime, and sulphuric acid, and less alkalies. The quantity of alkali in all of these soils is about equal to that found in the Rio Grande valley soils; much greater than is ordinarily found in soils devoted to agricultural purposes. But excluding No. 4, the quantity is not sufficient to interfere with their cultivation.

PECOS RIVER WATER.

Below are given two analyses of Pecos River water. No. 1 was collected at Pecos City, and received at the laboratory in January, 1889 Gave an alkaline reaction on boiling, and had alkaline taste. Suspended matter made up largely of red soil, that settled quickly on standing.

No. 2 was collected in Reeves County, and received at the laboratory in December, 1889. Gave, as No. 1 did, an alkaline reaction and possessed the same alkaline taste. Suspended matter made up more of silt and a lighter soil than in No. 1, and settled only after twenty-four hours' standing:

ANALYSES.	Grains per Gallon. No. 1.	No. 2.
Total solid contents	308.48	319.39
Soluble after evaporation	172.59	204.70
Total mineral matter	255.48	259.19
Total lime, as CaO	27.42	37.62
Total sulphuric acid, as SO_3	64.57	76.73
Total chlorine	39.05	65.03
Total alkalies, as chlorides	58.70	106.50
Total potash, as oxide	*	2 95
Total soda, as oxide	*	66.08
Total suspended matter	36.32	85.76

*Not separated.

It will be noticed there is considerable variation in the two analyses; the larger quantity of mineral matter appearing in No. 2. This is particularly true in case of the alkalies. When the last sample was collected the river was lower than in January previous. The total mineral matter is comparatively nearly the same, and very high. Of this the matter soluble after evaporation is also very great.

According to estimates in California, it takes about ten inches of water during a year to perfect a crop. This would probably be the smallest estimate that could be made for Western Texas when judiciously used in irrigating. One gallon of water will cover one and one-half ($1\frac{1}{2}$) square feet one inch deep, or six and two-thirds ($6\frac{2}{3}$) gallons per square foot is equal to ten inches depth of water. If we assume the alkalies in this water to be 58 grains to the gallon, as given in analysis No. 1, on every square foot of soil irrigated from the river there would be brought annually three hundred and eighty-six (386) grains of alkaline chlorides—consisting principally of sodium chloride—on a soil that already contains considerable quantity of alkali. The effect would, in time, necessarily be fatal to the use of the land for agricultural purposes.

It is possible that for a few years the water could be used for irrigation; especially if special crops were grown—those least affected by alkali. But in time there would be sufficient accumulation to destroy plant growth. The water contains some material that is valuable as plant food. The lime and sulphuric acid are in combination as the sulphate, or *gypsum;* this is very favorable to most river-formed soils, and to alkaline soils containing the alkaline carbonates. The river sediment added year by year to the soil would continually enrich it, but for the presence of the *alkalies.*

APPENDIX.

On page 10 Prof. Harrington makes this statement in regard to the effect of alkalies on the growth of crops: "But so far as I can ascertain, the maximum quantity of alkali that any crop would tolerate and still thrive and do well has not yet been determined. The character of the soil would undoubtedly have great influence in this matter." Such being the case, I have delayed the publication of this Bulletin that additional facts might be accumulated bearing upon this point, for it is one of the greatest importance to a large area in the Pecos Valley.

Both before and since the commencement of this examination there has been an experimental farm in operation above Pecos City, using the waters of the Pecos River for irrigation. Upon it have been grown fruits, vegetables, grains, grasses, etc., and the yield has been of such a character, both in quality and amount, as to encourage the construction of canals and ditches and a considerable extension of the irrigation facilities. The claim made by the operators of the experimental farm is that the manner of irrigation prevents the accumulation of the salt to any hurtful extent. The plats are flooded with water and the porous nature of the soil permits rapid drainage. By this means, it is thought by them that the water as it is applied washes out the soluble salt left by former applications, and in turn leaves only about the same quantity as before, as it is drained away or evaporates.

The facts, as I can learn them, are that up to the present, at least, no deleterious effects are noticeable from the application of the water. The crops continue to flourish, and there is no perceptible reason for expecting them to do otherwise while the water continues available as it is now.

That there is, however, an increase in the amount of salt in the land after irrigation is fully proved by the following analyses made of virgin soil and exactly similar soil near it, which had been irrigated for three years. The soils were carefully selected by Prof. W. F. Cummins, and analyses made by Mr. L. E. Magnenat, Chemist of the Survey.

Soil No. 1. Virgin Soil from Section 174, Block 34, H. & T. C. Ry. Co.

Soil No. 2. Unirrigated, Experimental Farm.

Soil No. 2a. Irrigated Soil, Experimental Farm.

Soil No. 3. Unirrigated Soil, Experimental Farm.

Soil No. 3a. Irrigated Soil, Experimental Farm.

	Total Water Soluble.	Sodium Chloride.
Soil No. 1	0.16 per cent.	0.046 per cent.
Soil No. 2	0.23 per cent.	0.044 per cent.
Soil No. 2a	0.38 per cent.	0.074 per cent.
Soil No. 3	0.48 per cent.	0.092 per cent.
Soil No. 3a	1.26 per cent.	0.164 per cent.

While this is true, however, the total amount of sodium chloride which is present in the soil is so small, and the annual addition from the water used in irrigation is so little, that it will require many years cultivation to bring the total amount into anything like a dangerous quantity. Thus, in soil No. 2 and 2a, the increase is only ten thousandths of one per cent annually, and even in the one showing the largest increase, No. 3 and 3a, the difference is only twenty-four thousandths of one per cent, at which rate it would require nearly forty years to bring the total up to even one per cent of the entire soil, an amount which in itself is far below an excess.

Having ascertained this fact by analysis, it then remained to determine the combination in which the large amounts of alkalies, which we have previously found in the soils, existed.

The water soluble matter was first analysed. Solution was effected by heating with water for five days over a water bath and the alkalies determined in the filtrate. The results are as follows:

	No. 1.	No. 5.	No. 6.
Potassium	0.024	0.07	Trace.
Sodium	0.220	0.25	0.11
Sulphuric Acid	0.500	0.60	Trace.
Carbonic Acid	Trace.	Trace.	Trace.
Chlorine	0.27	0.10	Trace.

In the water soluble material, therefore, the alkalies are present as sulphates and chlorides, with traces of sodium carbonate.

The total amounts of alkalies present were then determined in fresh portions by the method of Prof. L. Smith, with carbonate of lime and sal ammoniac, with the following results:

	No. 1.	No. 5.	No. 6.
Sodium	3.23	4.32	4.11
Potassium	2.61	2.77	1.58
Total	5.84	7.09	5.69

Taking into consideration the amounts of sulphuric acid, carbonic acid and chlorine present, as shown in the analyses, it is evident that the larger portion of the alkalies must exist as silicates, since there is nothing else for them to combine with. This is rendered the more certain by the consideration that the rock material from which the soils are derived is largely feldspathic in its nature, consisting of the intrusive porphyries which cover such an amount of the area West and North of that locality.

With this explanation, the apparent excess of alkalies is shown to be in no wise dangerous to the agricultural prospects of the valley.

The suggestion, however, of growth of crops least affected by alkalies might well be given attention, in so far as by proper rotation of alfalfa and other grass crops which take up larger quantities of alkalies, to keep the amount within proper bounds.

E. T. DUMBLE,
State Geologist.

Feb. 27th, 1892.